

Acceleration- vs. velocity-resolved constraint-based instantaneous task specification and estimation (iTASC) ¹

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1 Introduction

The instantaneous Task Specification and estimation using Constraints (iTASC) framework presented by De Schutter et al. [1] presents a constraint-based framework and particular sets of auxiliary coordinates to express task constraints and model geometric uncertainty. The constraint-based framework does not consider the robot joints nor the task frame as centric, instead it describes a robot task as an optimization problem consisting of a set of constraints, possibly formulated in multiple task frames, and one or multiple objective functions. The key advantages of iTASC over classical motion specifications are: (i) the composability of constraints, (ii) the reusability of constraints, (iii) the derivation of the control solution, and (iv) the modelling of uncertainty. The paper by De Schutter et al. only details a velocity-resolved control scheme. This abstract additionally presents an acceleration-resolved control scheme for iTASC. The control scheme includes the systematic treatment of uncertain and possibly time-varying geometric parameters in the task environment, which are modeled using auxiliary coordinates, estimated using a state estimator, and compensated for in the control law.

2 Acceleration-resolved iTASC

A velocity- or acceleration-resolved iTASC application consists of different connected kinematic chains or trees: (i) *Robots and Objects*, whose states are the joint coordinates q , and on which *object frames* are defined; (ii) *Virtual Kinematic Chains (VKC)* between two object frames, whose states are the feature coordinates χ_f ; (iii) *Uncertainty Kinematic Chains*, whose states are the uncertainty coordinates χ_u . The connected kinematic chains form kinematic loops, one for each task. A task consists of imposing constraints on the relative motion between two object frames. Therefore, the programmer chooses the outputs that have to be constrained by defining an *output equation* $y = f(q, \chi_f)$. The kinematic loops introduce extra constraints, expressed by the *loop closure equation* $l(q, \chi_f, \chi_u) = 0$.

By introducing an objective function, and taking into

account abovementioned constraints, the acceleration-resolved iTASC becomes an optimization problem resulting in the desired robot joint accelerations. In the experiments a prioritized, weighted damped least-squares solution is used to deal with underconstrained and/or overconstrained systems. The control input $u = T_{act}$ (joint torques) is calculated from the joint accelerations using feedback linearization.

3 Comparison and conclusion

Both the acceleration- and velocity-resolved iTASC schemes are independent of the type of lower level control on the robot, as can easily be seen in figure 1.

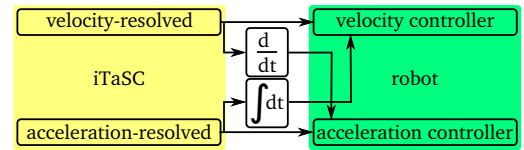


Figure 1: iTASC type vs. robot low-level control type

The acceleration scheme is more complex and requires more computational power than the velocity scheme. It however allows the developer to directly specify constraints and objective functions on the acceleration level.

The experimental validation and comparison of both control schemes involves a seven degree-of-freedom KUKA LWR4 arm, constrained by two tasks: an underconstrained figure tracing task at highest priority and a task keeping the robot joints as close to the initial joint positions as possible at lowest priority. A first experiment demonstrates the different solutions in joint space for the velocity- and acceleration resolved control schemes, because of the different optimization in the null space of the constraints. A second and third experiment, involving conflicting and discontinuous constraints, demonstrate the different first and second order transients between the control schemes, while reaching the same constrained goal functions. Nevertheless, both control schemes are instantaneous optimizations, and therefore no conclusions can be made concerning the global task optimum over the entire execution time.

References

- [1] J. De Schutter, et al. "Constraint-Based Task Specification and Estimation for Sensor-Based Robot Systems in the Presence of Geometric Uncertainty," IJRR 2007.

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